Planned Improvements to REMUS, a VSW MCM Semi-Autonomous Hydrographic Reconnaissance Vehicle System

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LONG-TERM GOALS

Current naval operational instructions task Navy Special Warfare forces (NSW) with the responsibility to conduct hydrographic and mine field reconnaissance missions in very shallow water (3-12 m) in forward areas throughout the world. NSW forces are required to map and monitor the extent of the sea mine threat and to identify the locations and extent of any gaps within a minefield. A successful mission requires clandestine or covert insertion, surface and subsurface reconnaissance, clandestine/covert extraction, and the production of a survey chart, that provides the Task Force Commander with the positions of identified mines, the coordinates of any mine field gaps, and the bathymetry of the mined region. This information must be available immediately, and in a suitable electronic format for transmission via a satellite communication link. Establishing the capability within the fleet to accomplish these missions with a small autonomous vehicle is the long-term objective of this research.

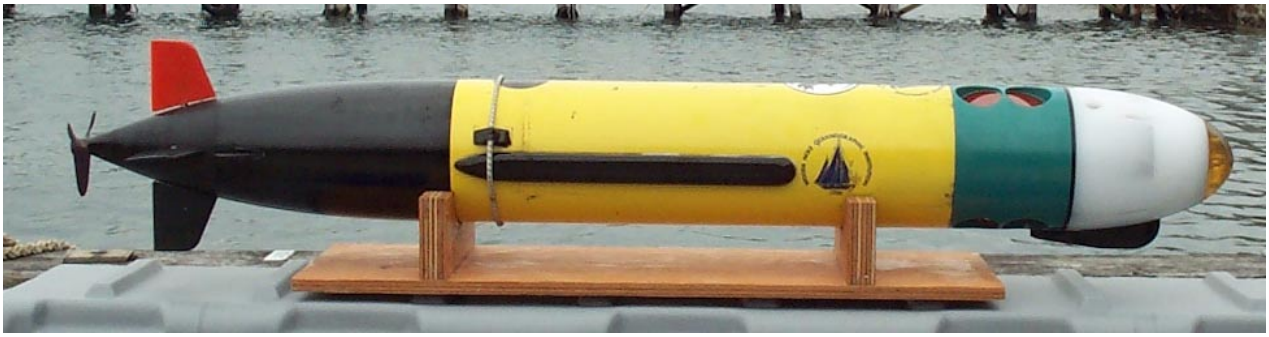

Figure 1. REMUS Vehicle

OBJECTIVES

Robust and practical Autonomous Underwater Vehicle (AUV) operations will provide the Navy with an alternative to traditional diver based minefield and hydrographic reconnaissance techniques. The overall objective of this work is to develop improved methodologies for performing covert coastal surveillance and reconnaissance in littoral regions throughout the world. AUVs will provide a means of obtaining data that would be otherwise unavailable except by exposing divers, mammals, and other operators to unacceptable

risks. AUVs provide the mission commander in the forward area with a choice far more palatable than sending men into a suspected minefield.

However, effectively integrating AUVs into the Navy requires addressing the needs of the fleet in an end to end manner: from procurement to training, mission planning, and operations, and afterwards, data dissemination. In recent years, REMUS has demonstrated that it is a reliable and cost effective platform for performing science based missions. From October 12-22 1999, at the Naval Amphibious Base (NAB), Coronado, and during Fleet Battle Experiment-Hotel (FBE-H) in August 2000, REMUS demonstrated that these same capabilities would make it a highly effective platform for military needs. Building on these capabilities and converting them to a military application is the objective of this research. These improvements will make REMUS a highly effective tool, enabling forward mission commanders to rapidly assess beach front areas, and providing them with information, options, and opportunities in a timely manner that would otherwise be unavailable.

In summary, our specific objectives are to:

- *Develop and demonstrate a multiple AUV navigation and target re-acquisition package*. The ability to operate multiple vehicles simultaneously will provide a simple and effective means of increasing search rates and area coverage. Improved navigation techniques will also permit remote tracking of vehicles and divers, and more rapid target re-acquisition, due to the inter-operability of navigation systems between different diver units and different AUVs.

- *Establish an acoustic telemetry capability*. In cooperation with the Advanced Engineering Laboratory at WHOI, the utility acoustic modem has been integrated into a REMUS test vehicle, evaluated, and then integrated into vehicles under development for NAVSEA PMS 325J.

- *Develop compact and low power multi-beam planar array technology*. The acoustic Doppler Velocity log and current meter has proven itself a valuable sensor augmenting AUV navigation. WHOI is collaborating with RD Instruments, Inc. of San Diego, CA, in the development of the next generation of Doppler Velocity Sensors (DVS), based on recent advances in multi-beam transducer and DSP technology. This task will develop reduced size electronics, permitting the delivery of a new DVS for REMUS, which is half the length and weight of the existing system, by the 4th quarter of FY99. During FY 2000 and 20001, the length and weight of this sensor will be cut in half again by using new phased array transducers. This sensor will also be integrated into a REMUS vehicle and tested.

- *Develop an optical imaging and payload delivery package*. WHOI is developing a payload delivery module for the deployment of bottom-mounted instrumentation, such as navigation transponders. In addition, an optical imaging sensor system will be developed, based on high-resolution electronic still imaging technology, for bottom classification and target imaging. This task will be expanded during FY01 to include the integration of a Dual Frequency Identification Sonar (DIDSON) that has been developed by Ed Belcher of the Applied Physics Laboratory at the University of Washington. Maneuvering tactics that are required for using this technology in mine identification will also be developed and demonstrated.

- *Develop data compilation and forwarding capabilities*. To successfully complete a VSW MCM mission, the data collected must be compiled and forwarded to the task force commander. WHOI

has developed an automated system that interfaces AUV mission planning and data transfer into defined DOD formats and software systems.

- *Support the development of Computer-Aided Detection and Classification (CAD/CAC) capability*. WHOI will provide sidescan sonar imagery with navigation data to CAD/CAC developers for processing on their systems. WHOI will assist these contractors in understanding file formats and in the overall evaluation of the performance of these systems. The out-year goal is the integration of CAD/CAC technology into the vehicle or system.

- *Participate in Field Evaluations*. Annual field evaluation trips are planned to test and demonstrate the progress on each of the major tasks, and to continue to obtain feedback from fleet personnel regarding the VSW MCM problems.

APPROACH

This research addresses a number of deficiencies identified in ANNEX A of the Capstone Requirements Document for Very Shallow Water Mine Countermeasures and Hydrographic Reconnaissance. As these improvements are developed, they will become available for integration into the SARHV system. A number of improvements, which may be incorporated into existing vehicles over the course of this program, will be developed. Each of these improvements will be field tested and validated through interactions with ONR, the VSW Detachment, and NAVSEA PMS 325J. In all cases, the improvements will strive to insure inter-operability with other VSW MCM/HR assets.

This research is being performed by Christopher von Alt and Thomas Austin, who are the co-principal investigators. Roger Stokey is developing vehicle software for the control system, and data compilation and forwarding. Lee Freitag is playing a key role in the acoustic modem effort. Mike Purcell and Robert Goldsborough are developing the payload delivery and optical imaging package. The improvements to the RD Instruments DVL are supported by Joel Young at RDI.. Gerald Dobeck of CSS supports the CAD/CAC effort and interfaces with other participants.

WORK COMPLETED

Multiple AUV Navigation and Target Re-Acquisition. The primary focus of this task is inter-operability between the SAHRV vehicles, other AUVs, and divers. Meetings have been held with members from Florida Atlantic University, Perry Technologies, ARL-UT, PMS 325J, and PMS-EOD. These meetings have focused on establishing requirements for a multi-AUV, multi-diver navigation and target re-acquisition package. The package will consist of spread spectrum acoustic beacons that operate in either transponder or synchronous transmission modes. The beacons will be compatible with other AUVs as well as diver operated units. The beacons will be designed to support operations at frequencies from 10 to 30 kHz. Progress to date includes the design and fabrication of the electronics and the design and fabrication of acoustic beacons that will utilize these beacons.

Development and Delivery of a Navicomputer. OSL developed a stand alone long baseline navigation system (the Navicomputer) for interface to an AUV. Both hardware and software were developed. The system was tested extensively in the water near WHOI and then delivered to Lockheed-Martin for integration into their CETUS AUV. Due to problems with their vehicle, Lockheed-Martin was not successful in demonstrating the use of the Navicomputer as a reacquisition tool during either FBE-H workup, or FBE-H.

Acoustic Telemetry. A WHOI utility acoustic modem and an Ocean Sensors 2000 CTD have been integrated into an existing REMUS vehicle. Testing of this complete system has occurred during the ONR/NAVOCEANO AUV Fest in November 1999, and during the FBE-H workup held at FL Atlantic University in June 2000.

Multi-Beam Planar Array Technology. A contract has been let to RDI Instruments to develop a multi-beam planar array for the REMUS vehicle. This array will be four inches long and provide both up looking and down looking capabilities. As part of this development, RDI was to develop a six-inch long, down looking only DVL for REMUS. This instrument has been developed and integrated into the SAHRV ADM vehicles. The instrument was tested during four-field evaluation, and is now working well. A second, half-length up/down instrument was to be delivered in mid December 1999. Work is still in progress on developing a 600 kHz phased array sonar. The associated electronics have been developed.

Data Compilation and Forwarding. During Fleet Battle Experiment-Hotel, bathymetry data collected by REMUS was imported directly into MEDAL. Target (mine) data has not been directly imported at this time; however, this capability will be demonstrated during FY01.

Computer Aided Detection and Classification (CAD/CAC). A number of CD ROMs, containing side scan sonar files and other information of interest, were prepared and delivered to the Coastal System Station in Panama City, FL in May and October and November of 1999, and during June and August 2000. The CD-ROMs contained information from sidescan surveys performed with REMUS.

Field Evaluations. Representatives from WHOI attended a joint planning meeting for Fleet Battle Experiment-Hotel sponsored by ONR in September. REMUS participated in the ONR/NAVOCEANO AUV fest in Gulf Port, Mississippi in November 1999; in the FBE-H workup in June 2000, and in the FBE-H in August/September 2000.

RESULTS

A preliminary design for the **multiple AUV navigation** and re-acquisition package has been developed. A series of meetings were held in late November and early December 1999. Board level designs and equipment fabrication were completed during the third quarter of FY00. Software for the new DSP-based design is currently under development.

The **WHOI acoustic utility modem** has been integrated into an existing REMUS vehicle. The ADM and EDM vehicles have been designed so that they can utilize this modem. The modem has been tested in local waters near WHOI, at the AUV fest in November 1999 in Gulf Port, Mississippi and during the FBE-H workup in June 2000.

The new **half-length RD DVL** has been developed and integrated into the SAHRV. This first planned product improvement has been transitioned into the NAVSEA PMS 32J acquisition program. This new design has been incorporated into the EDM models under development for NAVSEA.

Testing of CAD/CAC software on sonar images collected by REMUS has progressed. Initial efforts indicate that there is a strong possibility that this software can be used to simplify the post processing of sonar records collected in the field by SAHRV. An extensive data set of mines in shallow water was

collected by the new SAHRV ADM vehicles during a number of field evaluations this year. These data will be made available to the CAD/CAC team.

At the recent **Fleet Battle Experiment Hotel** exercise during August and September 2000, REMUS was tasked to survey an area known as "Red Beach", a beachfront southwest of Panama City, Florida. This area consisted of a 3400 meter lane, 914 meters (1000 yards) wide. Water depths ranged from 11 meters offshore to less than three inches the near shore region. The area covered over three square kilometers of ocean, and was equivalent to 563 football fields (including the end zones!). It was REMUS' job to find the mines in this region, and provide latitude-longitude coordinates for target reacquisition by other assets. The survey of Red Beach was accomplished over a 3-day period, with mission durations of 6:24, 5:57, and 2:49 hours, for a total survey time just over 15 hours. The sidescan system produced 1402 megabytes of data in 1152 files.

In all, from a merger of the three surveys, 42 mine-like targets were located with 67 different side scan images. (In performing 100 percent insonification, there is some overlap of adjacent rows, so some targets are imaged twice. These are automatically merged into a single target.) Ground truth later revealed that there were 33 actual mines placed in the vicinity of Red Beach. REMUS found all but one, which was later shown to be outside of the actual defined survey area. In short, REMUS found 32 of 32 available mines; thus, probability of detection was 100%. The remaining 10 are false targets. Of these, 6 were the result of navigational errors that caused valid targets to be listed twice, three were mine-like objects that apparently were not mines (no attempt was made at classification), and the last was a PDM-2 that we believe to be an omission in the ground truth.

Target localization was extremely accurate. The average position error for all 32 targets was 7.5 meters. This is sufficiently small that both GPS granularity and accuracy become a significant factor. The worst case error, 18.2 meters, was for a PDM-3 that was detected at a range of 2000 and 1800 meters from the two navigation transponders, well beyond the recommended maximum working range of 1500 meters.

IMPACT/APPLICATIONS

The United States Special Operations Command (USSOCOM) in Tampa, FL has approved an Operational Requirements Document (ORD) that describes a very shallow water mine counter measure and a semi-autonomous hydrographic reconnaissance system. This document details a system which is essentially identical to the technology which has been developed at WHOI and states that no change in the Naval Special Warfare force structure will be required to support this technology. The ORD also establishes that a full operational capability will be achieved when a complete inventory of 28 vehicles with full logistic support and training is in place. Currently, full operational capability is called for in FY01. It is anticipated that the results of this research will be transitioned into the SAHRV system in the future.

TRANSITIONS

An objective of this proposal is to provide NSW teams with an Initial Operating Capability (equipment and training) to conduct shallow water minefield and hydrographic reconnaissance with small autonomous underwater vehicles by FY01. It is anticipated that the results of this research will be incorporated into the SAHRV system sometime in FY02 or 03.

The Program Management Office Explosive Ordnance Disposal (PMS-EOD) has released a Broad Agency Announcement requesting information on untethered underwater mine counter measure systems that operate in the VSW zone (10-40 ft.) As a result of fair and open competition in this area, WHOI is being awarded a

contract by EOD to fabricate two vehicles and provide support services for the next two years on this program. This is the second major program that is directly and rapidly transitioning basic research to the fleet.

RELATED PROJECTS

1. Semi-Autonomous Hydrographic Reconnaissance Vehicle PMS 325J
2. Diver and AUV Systems and Technologies for VSW/SZ MCM Missions
3. Autonomous Platform Systems for VSW/SZ MCM
4. Untethered Unmanned Underwater Mine Counter Measures (PMS-EOD) BAA 00-002

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None

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